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ENGINEERING-SCIENCE, INC.

401 Harrison Oaks Boulevard, Suite 210 • Cary, North Carolina 27513 • (919) 677-0080 • Fax: (919) 677-0118

July 9, 1993

Mr. James Williams
Technical Program Manager
AFCEE/ESC Building 624 W
Brooks AFB, Texas 78235-5000

RE: Interim Bioventing Pilot Test Results Letter Report
IRP Site ST-27 (Building 575)
Charleston Air Force Base, South Carolina

Dear Mr. Williams:

Engineering-Science, Inc. (ES) is pleased to present the interim test results of the bioventing pilot study at Installation Restoration Program (IRP) Site ST-27. Initial testing of site parameters was conducted in May, 1993 and consisted of an air permeability test and *in-situ* respiration tests. These data are presented herein and have been evaluated to determine the feasibility of continuing with the bioventing initiative at this site.

This letter report replaces the formal interim results report typically provided by ES under the bioventing program. Interim test results are presented at this time pending startup of the one-year bioventing pilot study. The extended pilot study was postponed indefinitely until liquid-phase product recovery and/or vapor control measures can be implemented at the site.

Site Description

IRP Site ST-27 is located on the western edge of the MAC Maintenance Apron adjacent to Maintenance Building 575. It is operated as an aircraft maintenance hanger and fuel storage facility. Several underground storage tanks (USTs) containing JP-4 jet fuel and MOGAS are located at the site. Releases of JP-4 fuel, and possibly gasoline, have occurred from the UST systems. These releases have contributed to both soil and groundwater contamination, with some liquid-phase product reaching the saturated zone. The site is covered by 12 to 14 inches of asphalt and concrete. Figure 1 shows a site map and locations of existing monitoring wells.

Soil Vapor Survey of Test Area

Engineering-Science previously conducted a limited soil vapor survey of the site during a base-wide search of candidate bioventing sites. Seven soil gas points were advanced on the west side of Building 575 in an area of known soil and groundwater contamination. Soil gas samples were collected from above the water table at depths of 2 feet and 3 feet below ground surface (bgs). The soil gas samples were field-screened for oxygen (O_2), carbon dioxide (CO_2), and total volatile petroleum hydrocarbons (TVPH).

Results of the soil gas survey indicate that the soils are oxygen-depleted and have elevated carbon dioxide concentrations throughout the test area. TVPH organic vapors exceeded 20,000 parts per million (ppm) on the field instrument at all test points. These results suggest that subsurface conditions are largely anaerobic and that significant vapor-phase contamination exists beneath the concrete pad. Details of the soil gas survey are presented in the Draft Bioventing Work Plan for Site ST-27 prepared by ES (March 31, 1993).

Vent Well Installation

One air injection vent well (VW) was installed at the site for interim testing and possible long-term use during the bioventing study. The VW was located within the center of the oxygen-depleted area identified during the soil gas survey. The VW was placed at a sufficient distance from Building 575 so that air would not be injected directly beneath the building and to monitor potential vapor displacement toward the building. Figure 2 shows the location of the VW relative to the site features. This VW can be used for air injection during full-scale bioventing operations.

The VW was installed using a 4-inch diameter hand auger and was constructed with 2-inch diameter PVC screens and casing. Groundwater was encountered at a depth of 5 feet bgs during the VW installation. Historical water level data for this site indicate that large seasonal fluctuations are common and that the average water table depth is typically 7 to 9 feet bgs during the dry season. ES installed the bottom of the VW screen beneath the water table to a total depth of 9.9 feet bgs to ensure that an adequate length of screen would be exposed in the unsaturated zone as the water table declines. Approximately 2 feet of screen was exposed above the water table after the VW was installed.

Figure 3 shows the construction details for the VW. Two threaded screen sections were used to construct the well. The upper 2.5-foot section consists of 0.020-inch slotted screens, while the lower 5-foot section consists of 0.010-inch slotted screens. A bolted 12-inch diameter manhole and locking expansion plug were used to complete the well.

Monitoring Point Installations

Four vapor/pressure monitoring points (MPs) were installed according to the work plan and bioventing test protocols. Three of the MPs (MPA-3.5, MPB-3.5, MPC-3.5) were installed on 10-foot centers between the VW and Building 575, as shown in Figure 2. A background MP, designated as BG-3.5, was installed 153 feet northwest of the VW in clean soils outside of the concrete aircraft apron area. The background MP was used to monitor background soil gas conditions not affected by hydrocarbon contamination.

Each of the MPs was constructed using 0.5-inch PVC screen and casing. The top of each MP was fitted air tight with a gas ball valve equipped with a hose barb. Two MPs (MPA-3.5 and MPC-3.5) were equipped with thermocouple probes to measure soil temperature. All of the MPs were installed to a total depth of 3.5 feet bgs, with the screen intervals placed from 3.0 to 3.5 feet bgs. This screened interval is expected

to remain above the water table for most of the year except during anomolously-high water table conditions. Figure 4 shows the construction schematics for the MPs. All three MPs could potentially be used during full-scale bioventing operations.

Soil Sampling Results

During installation of the VW and MP boreholes, ES collected soil samples at regular intervals for field screening of organic vapors. Three sets of samples were collected for laboratory analyses. Soil samples were collected for laboratory analysis from the VW, MPA-3.5, and MPC-3.5. Since there were no significant differences in organic vapor concentrations with depth, soil samples for laboratory analyses were collected from the same unsaturated zone depths as the screened intervals of the MPs and VW.

The three sets of soil samples were analyzed by the laboratory for these parameters: total recoverable petroleum hydrocarbons (TRPH); benzene, toluene, ethylbenzene, xylenes (BTEX); iron; alkalinity; pH; total Kjeldahl nitrogen (TKN); phosphates; percent moisture; and particle size distribution. Table 1 presents the results of these analyses. TRPH concentrations ranged from nondetectable (ND) at the VW to 29 milligrams per kilogram (mg/kg) at MPC-3.5. Soil TRPH concentrations tended to increase toward the release area in the vicinity of the USTs. The soil BTEX concentrations ranged from ND to 0.00020 mg/kg for the individual compounds.

Soil Gas Sampling Results

Three soil gas samples were collected using SUMMA[R] canisters, one each from MPA-3.5, MPC-3.5, and the VW. The samples were collected according to bioventing program protocols and were analyzed for total volatile hydrocarbons (TVH) and BTEX compounds. Analytical results indicate elevated soil gas TVH concentrations ranging from 75,000 parts per million by volume (ppmv) at MPC-3.5 to 160,000 ppmv at the VW. Soil gas BTEX concentrations ranged from 35 ppmv to 990 ppmv for individual BTEX compounds. Table 1 lists the soil gas sampling results. Soil and soil gas sampling results suggests that the majority of the soil contamination in the test area exists in the vapor phase.

Lithologic Characterization

Soils encountered during the MP and VW installations consisted primarily of yellow-brown to gray, silty fine sands in the upper four feet of the soil column. This silty sand unit is rather consistent across the site. The soils contain a greater silt and clay fraction starting at a depth of approximately 4 feet bgs, although the soil matrix remains predominantly a fine sand. Soil mottling and occasional discontinuous clay lenses were observed from 6 feet bgs to 10 feet bgs in the VW boring. As the shallow soils are relatively uniform above the water table, ES has not prepared boring logs or lithologic cross sections for this site.

Pilot Test Results

ES conducted a soil air permeability test and *in-situ* respiration tests at the site in May, 1993. As discussed above, pre-test soil gas samples were collected for qualitative

(field screening) analyses and quantitative (laboratory) analyses prior to conducting the tests. Sampling results are listed in Table 1. Test procedures and results for each of the tests are discussed in the following sections.

Air Permeability Test

A soil air permeability test was conducted at this site on May 7, 1993 according to AFCEE protocol procedures. Using a rotary vane compressor pump, air was injected in the VW at a flow rate of 3.67 standard cubic feet per minute (scfm). Pressure responses were measured at each of the closest monitoring points (MPA-3.5, MPB-3.5, and MPC-3.5) using either a digital manometer or Magnehelic pressure gauges. Air was injected for 142 minutes until relative steady-state pressures were achieved and maintained at the MPs. Table 2 contains the time-pressure responses for each MP.

Using the HyperVentilate^{R} model, calculated soil gas permeabilities ranged from 2.7 darcys (MPA-3.5) to 6.1 darcys (MPC-3.5) at the 3.5-foot depth. These values are typical for a fine-to-medium sand soil matrix. Initial air permeability testing indicates that a soil pressure response can be induced at distances exceeding 30 feet. Approximate steady-state pressure at MPC-3.5 (r=30 feet) was 9.91 inches of water. It is likely that soil pressure responses were created at distances of 40 to 50 feet from the VW during the test.

Soil pressure responses do not necessarily equate to soil gas flow when determining an effective radius of influence. The ability to actually transport gases (oxygen) through the soil column is far more important in a bioventing design than the ability to create just a pressure response. Soil gas composition (O_2, CO_2, TVH) was measured at the MPs during the air permeability test to monitor the diffusion of injected air (oxygen) outward from the VW. After 120 minutes of air injection, O_2 had increased from 0.0% to 13.5% at MPA-3.5 and from 0.0% to 0.5% at MPB-3.5. No significant changes were seen at MPC-3.5 during this time. These data suggest that during the test period, O_2 diffused outward at least 20 feet from the VW at the given test air flow rates and injection pressures.

***In-Situ* Respiration Tests**

An *in-situ* respiration test was conducted at the VW and the three closest MPs beginning on May 12, 1993. Respiration testing was conducted in accordance with procedures outlined in the bioventing protocol document referenced in the work plan submitted by ES. Testing procedures included helium injection into the MPs for use as a tracer. Air with a 4.5% helium mixture was injected into the three MPs for 17.5 hours. Air injection into adjacent MPs also increased the O_2 levels in the VW from a pretest concentration of 0.0% to 19.8% after 17 hours. This allowed *in-situ* respiration testing to be conducted at the VW as well. Background respiration testing was not conducted because the background MP (BG-3.5) contained initial O_2 levels of 19.5%, indicating that abiotic oxygen uptake was not a factor at the site.

Oxygen uptake and CO_2 production were monitored for 28 hours during the respiration test. Attachment 1 contains the field data results and plots of O_2 utilization obtained during the test. Oxygen was readily utilized by indigenous soil

microorganisms, indicating microbial fuel degradation can be stimulated at the site by adding oxygen. Referencing Attachment 1, the "k" value shown on the graphs is the estimated oxygen utilization rate that is used to calculate fuel biodegradation rates. Oxygen utilization rates ranged from 0.006 percent per minute at the VW to 0.008 percent per minute at MPC-3.5. Recovered helium concentrations were relatively constant, indicating little or no O_2 was lost from the soil due to diffusion or leaks in the MP seals.

Assuming that no abiotic O_2 uptake occurred, the observed O_2 utilization rates indicate that between 160 to 1150 mg of hydrocarbons per kg of soil can be biodegraded per year at this site. These estimated biodegradation rates represent conditions at the pilot test study area. Actual biodegradation rates can be highly localized and may be affected by temperature, soil moisture, fuel (carbon) concentrations, and other factors.

Summary and Conclusions

Field testing has demonstrated that biodegradation of fuel contaminants can be stimulated at this site by the introduction of oxygen. It is possible that even greater biodegradation rates can be sustained closer to the spill source area where hydrocarbons are likely adsorbed to the soil matrix in greater concentrations. A large fraction of volatile hydrocarbons exist in the vapor phase at the test area, where they remain trapped by the overlying concrete. Emissions to the atmosphere during air injection were likely neglible due to the concrete covering the site. No vapor emissions were noted during the tests using a 3.67 scfm injection rate. Due to the elevated concentrations of volatile hydrocarbons in the soil gas, long-term injection of large quantities of air is not recommended, as this potentially could cause vapor migration into Building 575. ES recommends that the free-phase product source of these vapors be significantly reduced before a full-scale air injection system is installed at the site.

The sandy soils at the site are relatively permeable and allow significant soil gas flow at moderate pressures. The oxygen-delivery radius of influence is expected to exceed 25 feet per vent well at low air injection rates (3-5 scfm). A larger radius of oxygen influence is possible at higher injection rates; however, increased air injection rates will increase the probability of vapor migration and are not recommended at this time.

Should you have any questions regarding these interim results for the bioventing pilot test at Site ST-27, please contact me at (919) 677-0080, or Mr. Doug Downey of ES at (303) 831-8100.

Sincerely,

ENGINEERING-SCIENCE, INC.

S. Grant Watkins

S. Grant Watkins, P.G.
Site Manager

TABLES

TABLE 1

SOIL AND SOIL GAS ANALYTICAL RESULTS

IRP SITE ST-27

CHARLESTON AFB, SOUTH CAROLINA

Analyte (Units)[a/]	Sample Location-Depth (feet below ground surface)		
Soil Hydrocarbons	VW-4	MPA-3.5	MPC-3.5
TRPH (mg/kg)	ND[b/]	11	29
Benzene (mg/kg)	ND	ND	0.0055
Toluene (mg/kg)	0.00081	0.00091	0.015
Ethylbenzene (mg/kg)	0.00020	0.0011	0.0085
Xylenes (mg/kg)	0.0018	0.0090	0.035
Soil Gas Hydrocarbons	VW-5	MPA-3.5	MPC-3.5
TVH (ppmv)	160,000	120,000	75,000
Benzene (ppmv)	170	150	57
Toluene (ppmv)	990	550	130
Ethylbenzene (ppmv)	140	67	35
Xylenes (ppmv)	450	200	110
Soil Inorganics	VW1-4	MPA-3.5	MPC-3.5
Iron (mg/kg)	3,280	5,230	16,700
Alkalinity (mg/kg as $CaCO_3$)	85	260	49
pH (units)	6.6	7.3	6.2
TKN (mg/kg)	36	93	58
Phosphates (mg/kg)	51	80	95
Soil Physical Parameters	VW1-4	MPA-3.5	MPC-3.5
Moisture (% wt.)	9.7	13	19
Gravel (%)	0	0	0
Sand (%)	36.6	40.5	30.4
Silt (%)	58.2	53.3	57.5
Clay (%)	5.1	6.2	12.1
Soil Temperature (°F)		MPA-3.5	MPC-3.5
5/13/93 (A.M.)		73.0	71.0
5/14/93 (A.M.)		75.0	72.5

a/ TRPH = total recoverable petroleum hydrocarbons; mg/kg=milligrams per kilogram; TVH=total volatile hydrocarbons; ppmv=parts per million, volume per volume; $CaCO_3$=calcium carbonate; TKN=total Kjeldahl nitrogen, °F=degrees Fahrenheit.

b/ ND = not detected.

TABLE 2

PRESSURE RESPONSES - AIR PERMEABILITY TEST

IRP SITE ST-27

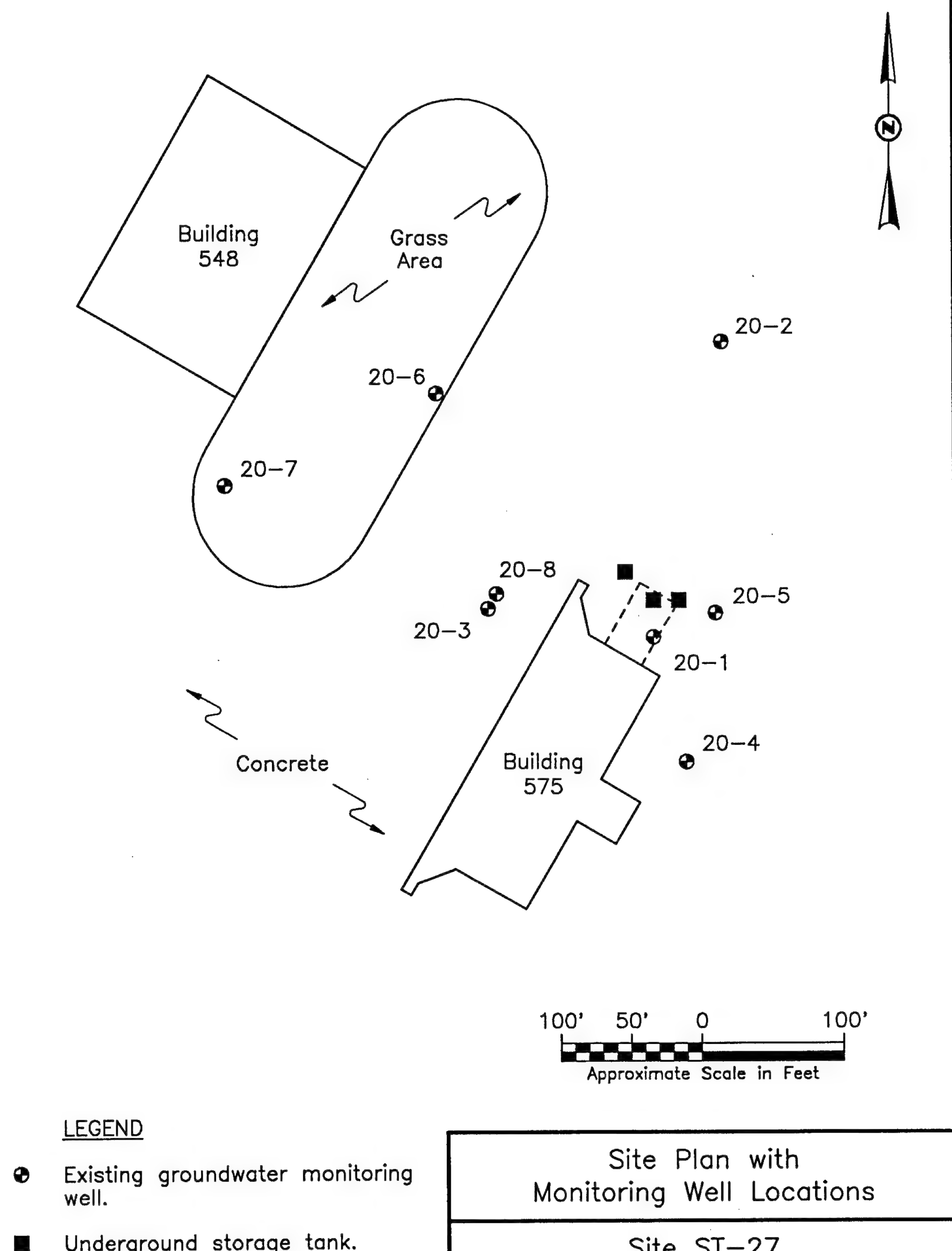
CHARLESTON AFB, SOUTH CAROLINA

Elapsed Time (Minutes)	Pressure Reading (inches of water)		
	MPA-3.5 (r=10')	MPB-3.5 (r=20')	MPC-3.5 (r=30')
0	0	0	0
0.5	1.21	NM	NM
1	3.54	0.10	0
2	7.44	0.83	0.08
3	10.16	1.84	0.26
4	12.16	2.85	0.56
5	13.66	3.79	0.94
6	14.85	4.63	1.25
7	15.84	5.36	1.65
8	16.64	6.03	2.00
9	17.32	6.63	2.40
10	17.88	7.17	2.75
12	18.80	8.11	3.45
14	19.53	8.91	4.10
16	20.50	9.57	4.65
18	20.50	10.15	5.10
20	21.25	10.63	5.54
22	21.75	11.05	5.92
24	21.80	11.41	6.27
26	21.85	11.73	6.57
28	22.00	12.00	6.83
30	22.25	12.24	7.08
32	22.25	12.46	7.30
34	22.40	12.65	7.52
36	22.50	12.82	7.68
38	22.75	13.00	7.87
40	22.75	13.14	8.02
45	23.00	13.46	8.06
50	23.10	13.68	8.58
55	23.20	13.87	8.81
60	23.25	14.00	8.98
70	23.25	14.17	9.23
80	23.25	14.30	9.40
90	23.25	14.46	9.60
100	23.25	14.55	9.75
110	23.25	14.64	9.84
120	23.25	14.69	9.91
142	Shut Down	Shut Down	Shut Down

NM = Not Measured

FIGURES

Figure 1



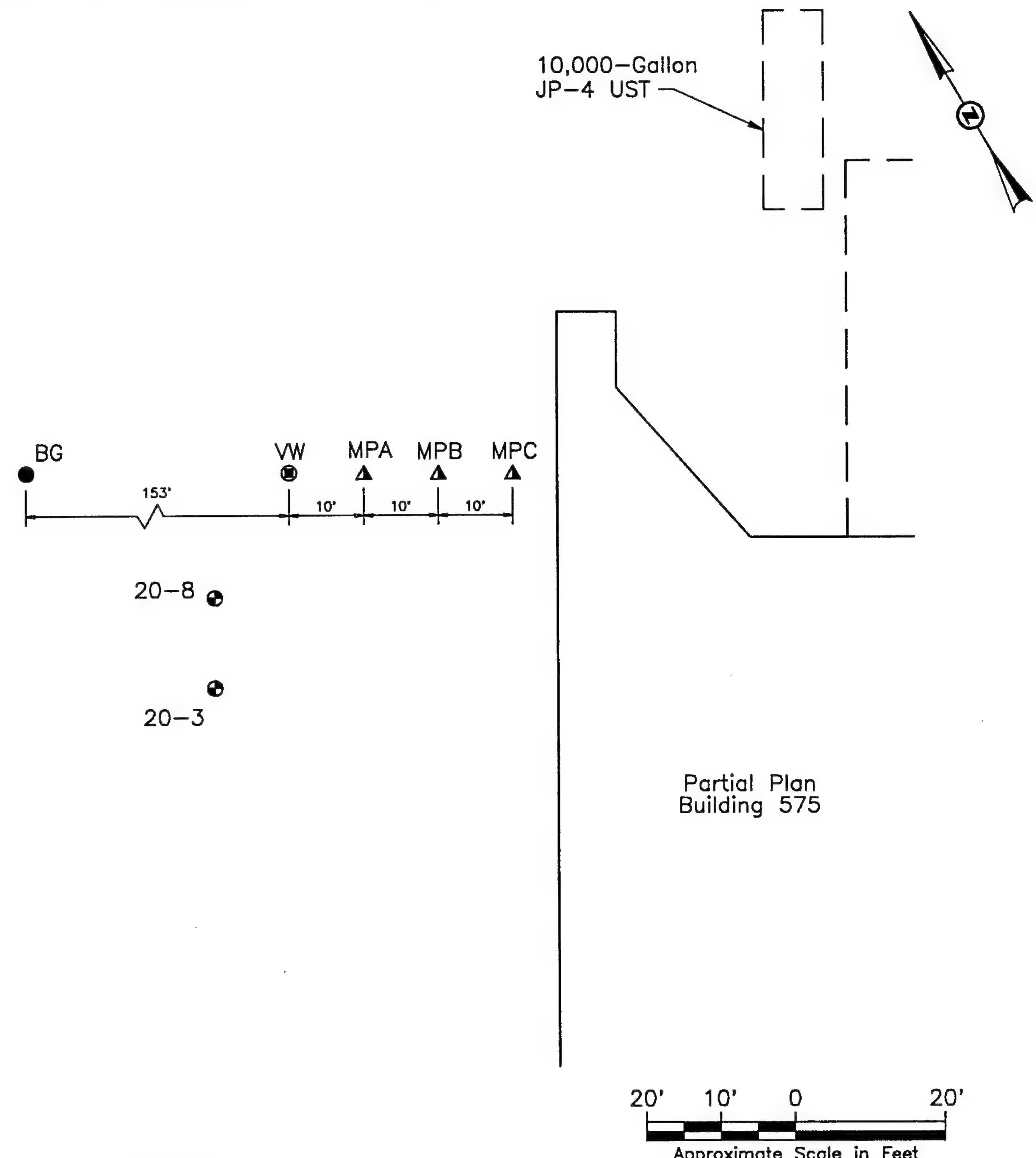
Site Plan with
Monitoring Well Locations

Site ST-27
Charleston A.F.B.
Charleston, South Carolina

DE268-17.dwg / 1=100 / 6-29-93 / TLP

ES ENGINEERING-SCIENCE

Figure 2



LEGEND

20–8 ⊕ Groundwater monitoring well.

VW ⊗ Air injection vent well.

MPA ▲ Soil vapor/pressure monitoring point.

BG ● Background monitoring point.

Air Injection Well and
Monitoring Point Locations

Site ST–27
Charleston A.F.B.
Charleston, South Carolina

DE268–18.dwg / 1=20 / 6–29–93 / TLP

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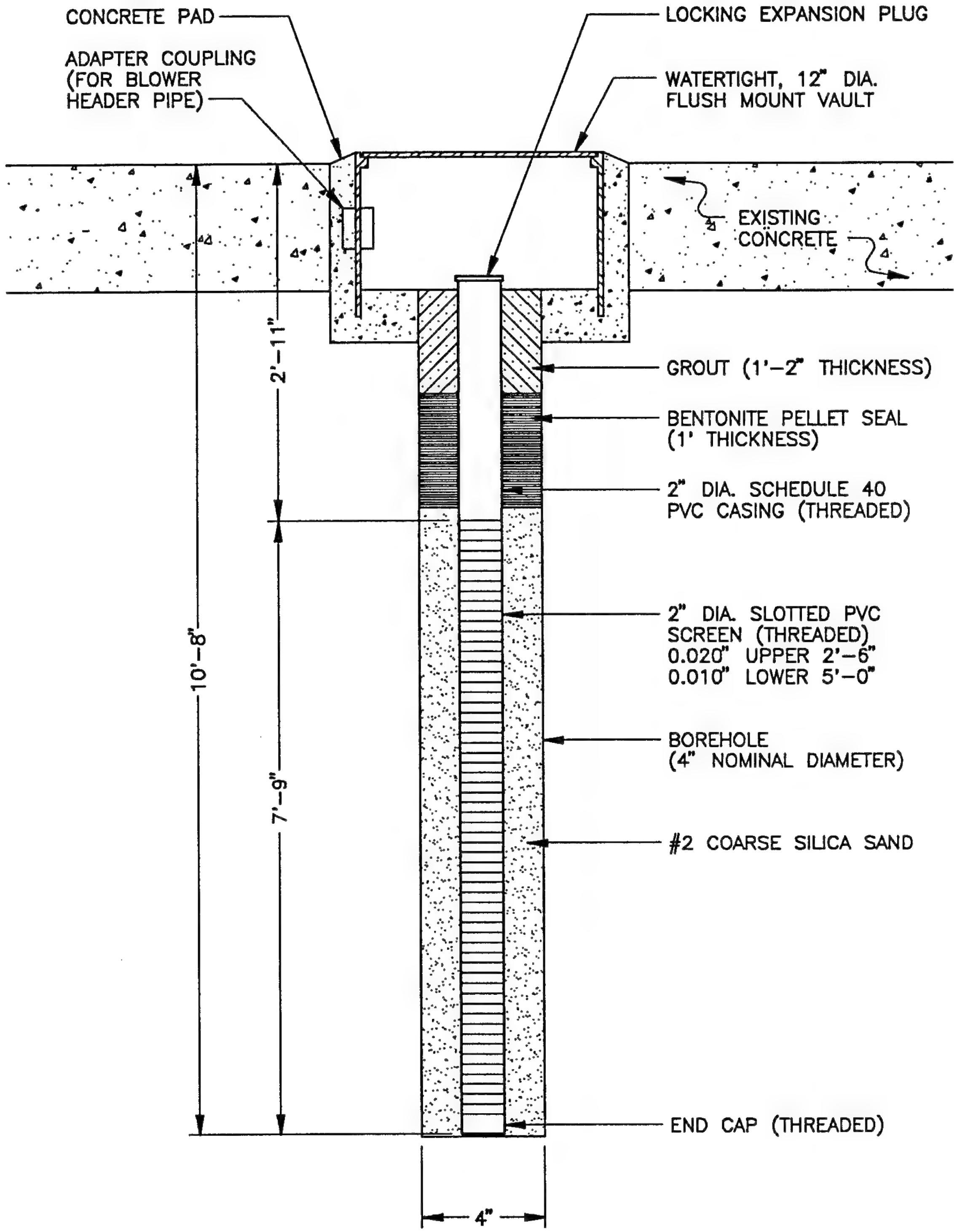

NOTES:

1. Drawing is not to scale.
2. Water table was 5.08' below land surface on 5-6-93.

As-Built Injection Vent Well Construction

Site ST-27
Charleston A.F.B.
Charleston, South Carolina

DE268-19.dwg / 1=1 / 6-30-93 / TLP

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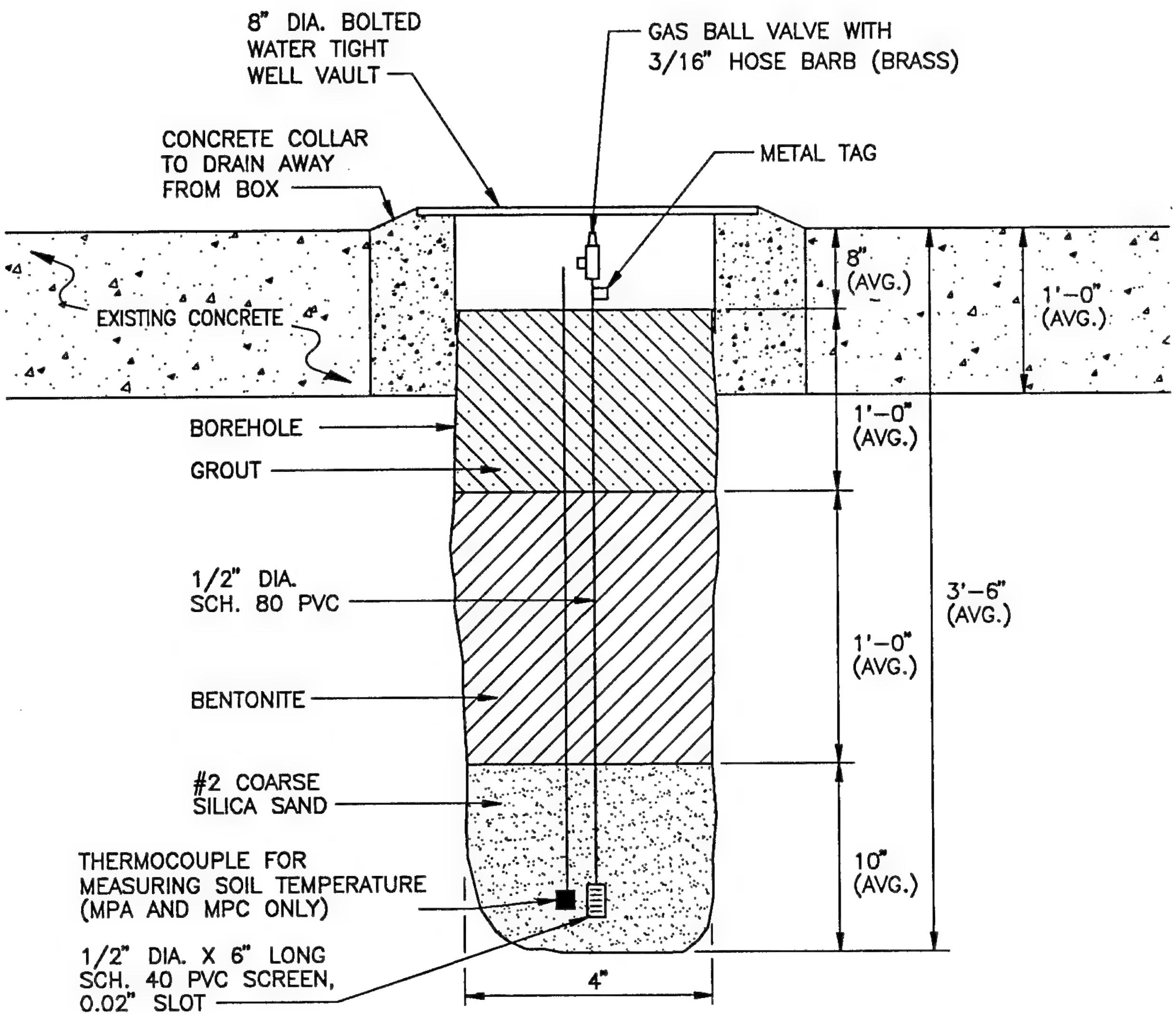

DRAWING IS NOT TO SCALE

As-Built Monitoring Point Construction Detail

Site ST-27
Charleston A.F.B.
Charleston, South Carolina

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DE268-20.dwg / 1=1 / 6-29-93 / TLP

ATTACHMENT 1

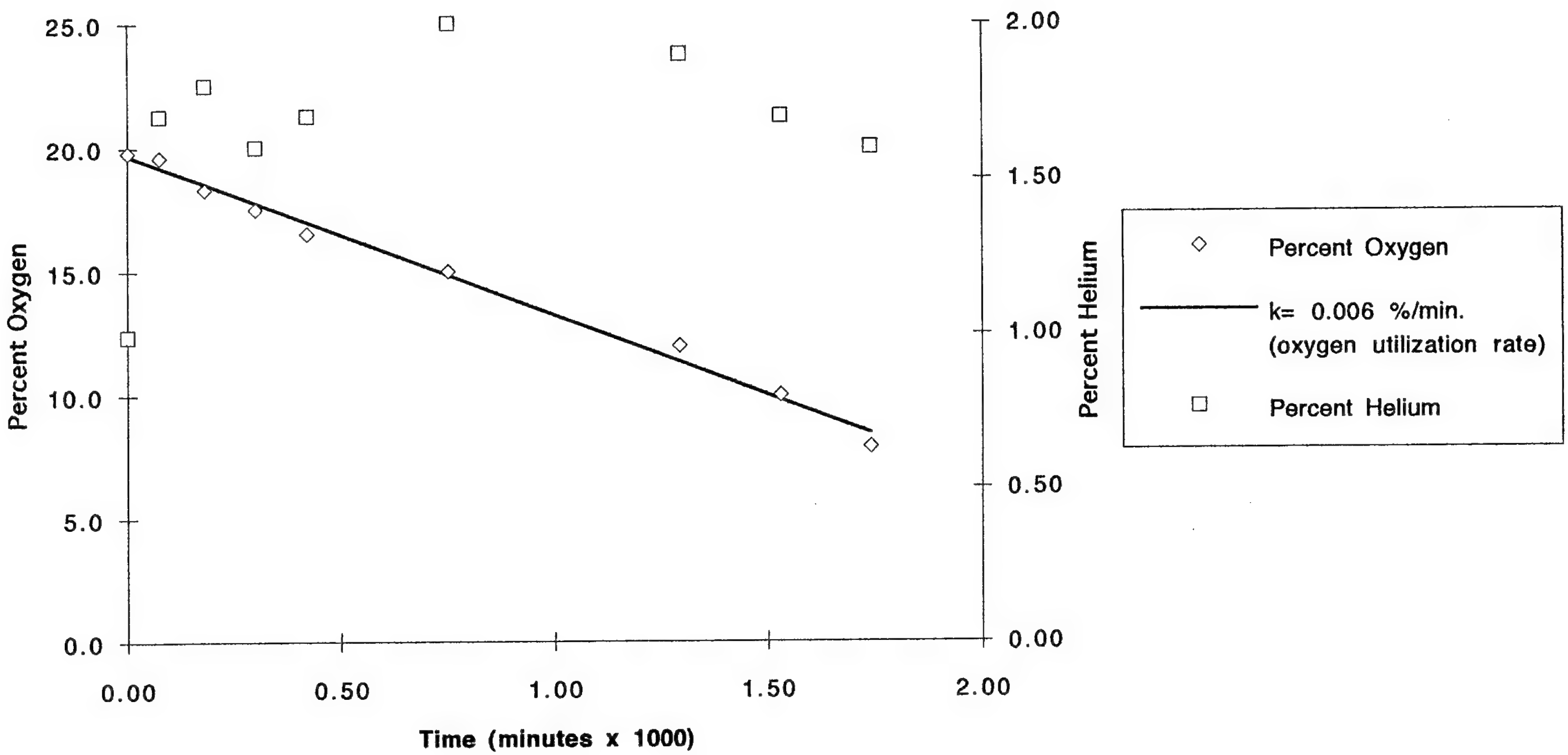
RESPIRATION TEST FIELD DATA AND OXYGEN UTILIZATION GRAPHS

Respiration Test
Site ST-27
Charleston AFB, SC

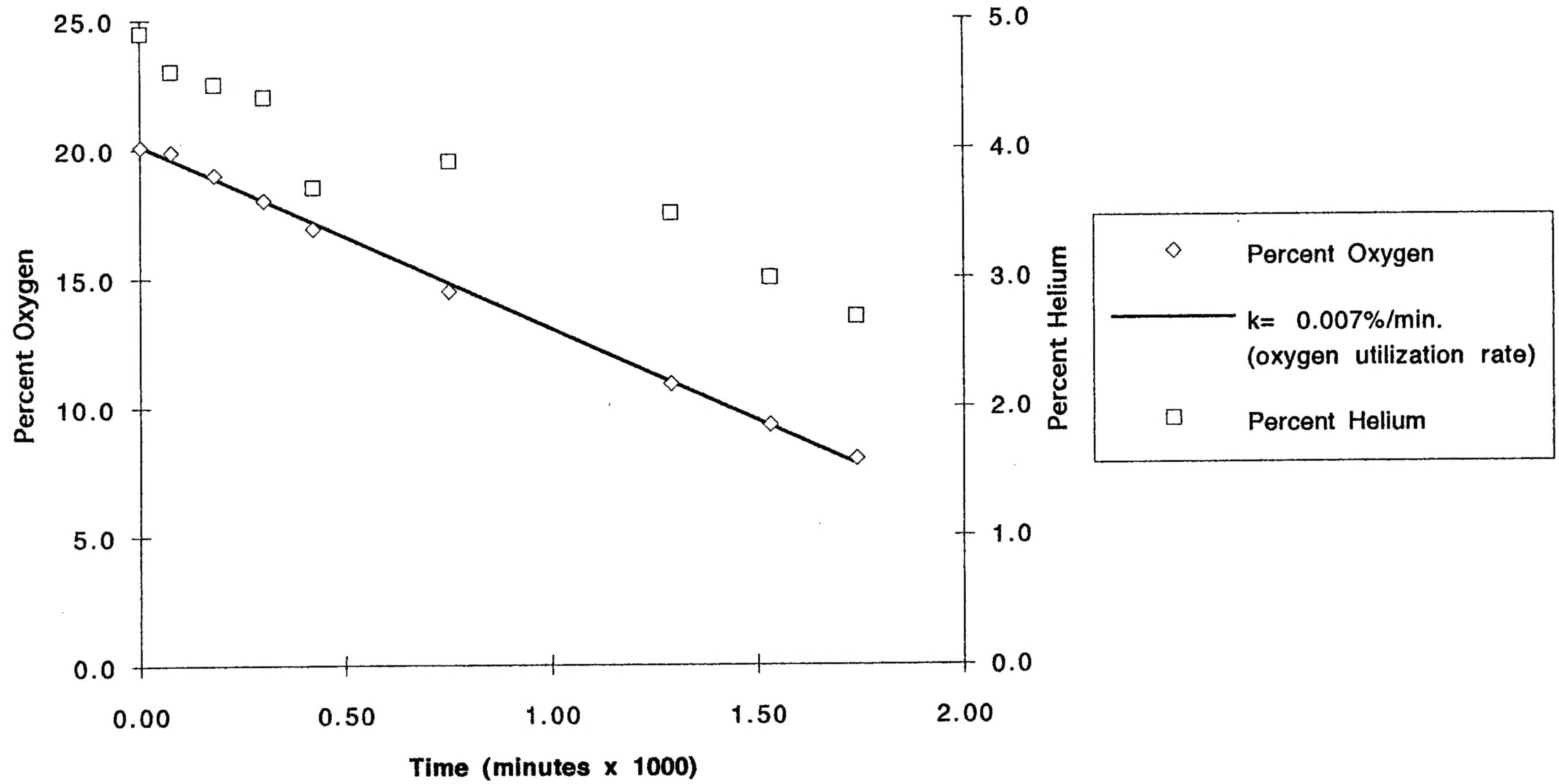
Monitoring Point	Date	Days Elapsed (frac. days)	Time	Hrs elapsed (fractional days)	Days Elapsed	Elapsed Time (min. x 1000)	O2%	CO2%	Total Hydro-carbon	Helium	Comments	Trend of O2/Time	New x-values	k
MPA-3.5	05/13/93	0.00	11:00	0.00	0.00	0.00	20.1	0.1	110	4.9	Temp = 73.0° F	20.1304309	0	0.00709
MPA-3.5	05/13/93	0.00	12:15	0.05	0.05	0.08	19.9	0.25	110	4.6		7.79016878	1.74	
MPA-3.5	05/13/93	0.00	14:00	0.13	0.13	0.18	19.0	0.3	120	4.5				
MPA-3.5	05/13/93	0.00	16:00	0.21	0.21	0.30	18.0	0.3	440	4.4				
MPA-3.5	05/13/93	0.00	18:00	0.29	0.29	0.42	16.9	0.3	660	3.7	Temp = 74.8° F			
MPA-3.5	05/13/93	0.00	23:30	0.52	0.52	0.75	14.5	0.4	1200	3.9				
MPA-3.5	05/14/93	1.00	08:30	-0.10	0.90	1.29	10.9	0.65	2600	3.5	Temp = 75.0° F			
MPA-3.5	05/14/93	1.00	12:30	0.06	1.06	1.53	9.3	0.75	2400	3.0	Recalibrated TPH meter			
MPA-3.5	05/14/93	1.00	16:00	0.21	1.21	1.74	8.0	0.75	2600	2.7	Temp = 74.7° F Low battery in TPH meter			
MPB-3.5	05/13/93	0.00	11:00	0.00	0.00	0.00	20.1	0.1	130	4.4		20.0769114	0	0.00668
MPB-3.5	05/13/93	0.00	12:15	0.05	0.05	0.08	19.8	0.25	160	4.4		8.45138513	1.74	
MPB-3.5	05/13/93	0.00	14:00	0.13	0.13	0.18	19.0	0.3	76	5.0				
MPB-3.5	05/13/93	0.00	16:00	0.21	0.21	0.30	17.9	0.3	380	4.6				
MPB-3.5	05/13/93	0.00	18:00	0.29	0.29	0.42	17.1	0.3	570	4.3				
MPB-3.5	05/13/93	0.00	23:30	0.52	0.52	0.75	14.9	0.5	960	4.7				
MPB-3.5	05/14/93	1.00	08:30	-0.10	0.90	1.29	11.5	0.6	1100	4.0				
MPB-3.5	05/14/93	1.00	12:30	0.06	1.06	1.53	9.9	0.6	1000	3.6	Recalibrated TPH meter			
MPB-3.5	05/14/93	1.00	16:00	0.21	1.21	1.74	8.5	0.3	1050	3.4	Low battery in TPH meter			
MPC-3.5	05/13/93	0.00	11:00	0.00	0.00	0.00	20.0	0.25	105	4.4	Temp = 71.0° F	19.5192515	0	0.00819
MPC-3.5	05/13/93	0.00	12:15	0.05	0.05	0.08	19.5	0.25	140	4.9		5.26889688	1.74	
MPC-3.5	05/13/93	0.00	14:00	0.13	0.13	0.18	18.2	0.3	220	5.1				
MPC-3.5	05/13/93	0.00	16:00	0.21	0.21	0.30	16.7	0.3	180	4.6				
MPC-3.5	05/13/93	0.00	18:00	0.29	0.29	0.42	15.5	0.3	240	4.6	Temp = 72.5° F			
MPC-3.5	05/13/93	0.00	23:30	0.52	0.52	0.75	12.7	0.45	380	5.2				
MPC-3.5	05/14/93	1.00	08:30	-0.10	0.90	1.29	8.7	0.6	620	4.4	Temp = 72.5° F			
MPC-3.5	05/14/93	1.00	12:30	0.06	1.06	1.53	7.0	0.6	530	3.9	Recalibrated TPH meter			
MPC-3.5	05/14/93	1.00	16:00	0.21	1.21	1.74	5.9	0.6	600	3.6	Temp = 72.3° F Low battery in TPH meter			
VW-5	05/13/93	0.00	11:00	0.00	0.00	0.00	19.8	1.0	9400	0.99	Pressure = 12.96"H2O	19.6879177	0	0.00646
VW-5	05/13/93	0.00	12:15	0.05	0.05	0.08	19.6	1.1	>10000	1.7		8.45024213	1.74	

VW-5	05/13/93	0.00	14:00	0.13	0.13	0.18	18.3	1.5	>10000	1.8				
VW-5	05/13/93	0.00	16:00	0.21	0.21	0.30	17.5	1.5	>10000	1.6				
VW-5	05/13/93	0.00	18:00	0.29	0.29	0.42	16.5	1.7	9900	1.7				
VW-5	05/13/93	0.00	23:30	0.52	0.52	0.75	15.0	2.0	>10000	2.0				
VW-5	05/14/93	1.00	08:30	-0.10	0.90	1.29	12.0	2.5	>10000	1.9				
VW-5	05/14/93	1.00	12:30	0.06	1.06	1.53	10.0	2.7	8200	1.7	Recalibrated TPH meter			
VW-5	05/14/93	1.00	16:00	0.21	1.21	1.74	7.9	3.4	8300	1.6	Low battery in TPH meter			

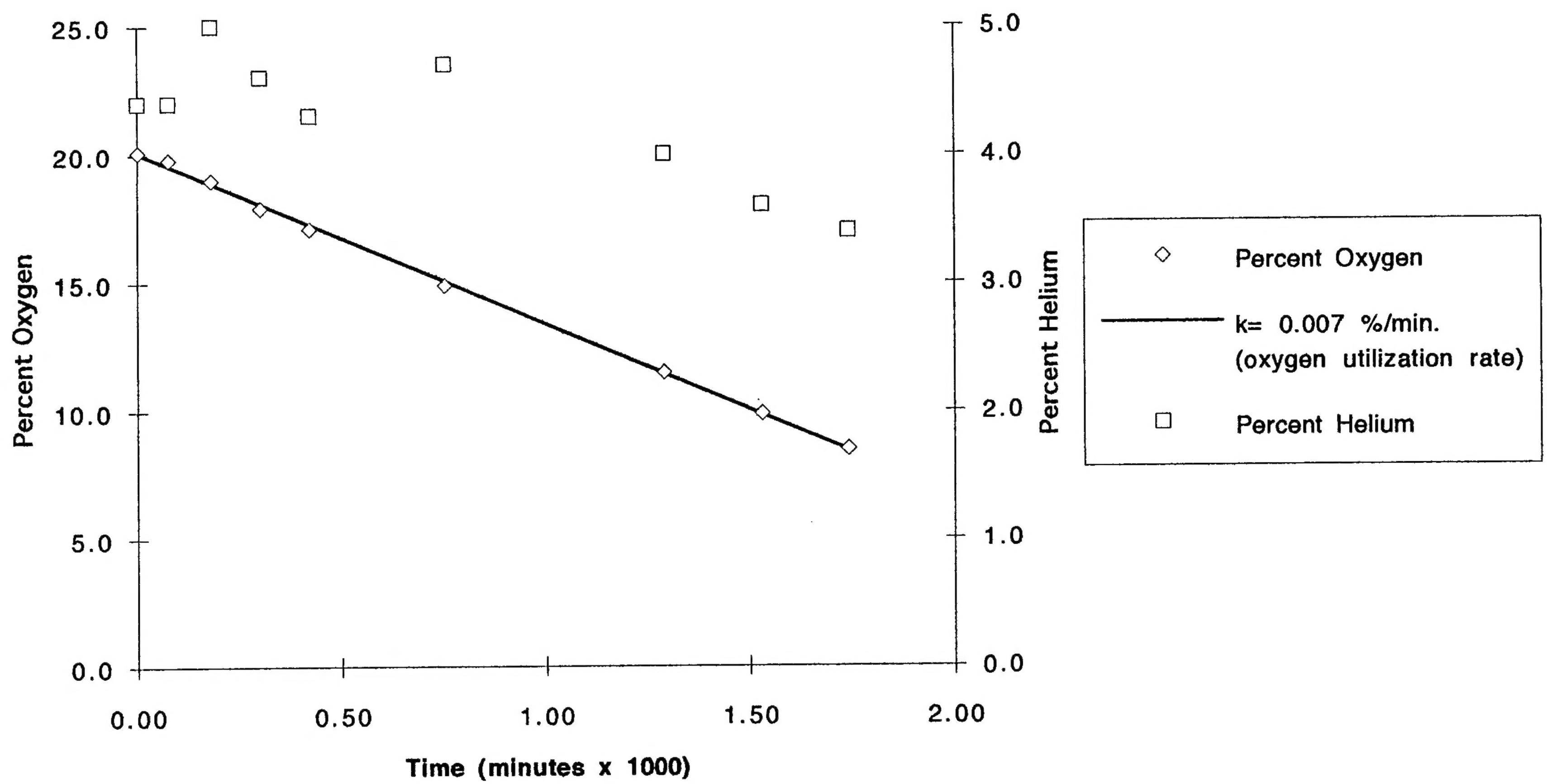
Respiration Test
Site ST-27
Oxygen and Helium Concentrations
Vent Well
Charleston AFB, SC

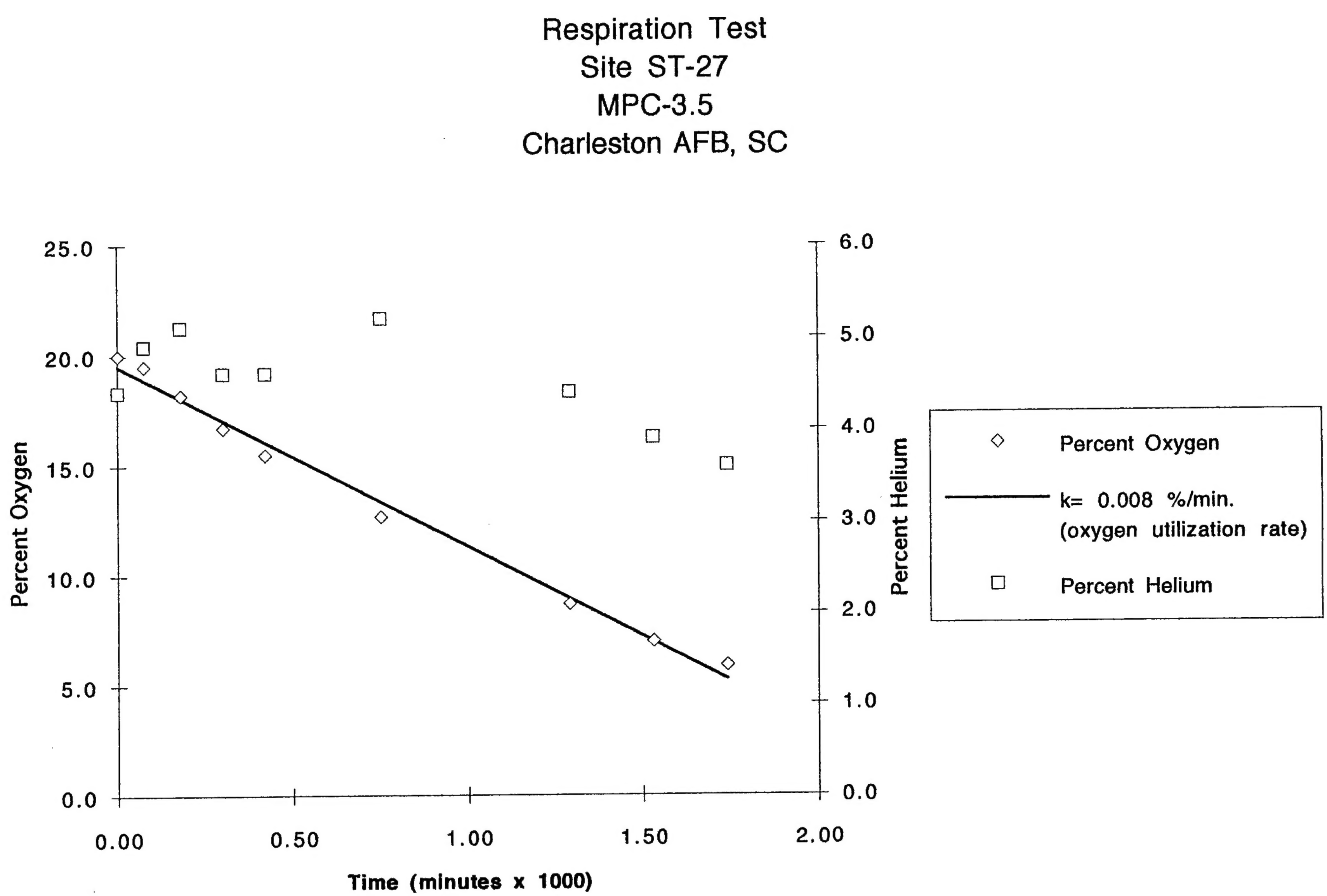


Respiration Test
Site ST-27
Oxygen and Helium Concentrations
MPA-3.5
Charleston AFB, SC



Respiration Test
Site ST-27
Oxygen and Helium Concentrations
MPB-3.5
Charleston AFB, SC





Respiration Test
Site ST-27
MPC-3.5
Charleston AFB, SC
Percent Oxygen
25.0
20.0
15.0
10.0
5.0
0.0
Percent Helium
6.0
5.0
4.0
3.0
2.0
1.0
0.0
0.00
0.50
1.00
1.50
2.00
Time (minutes x 1000)
Percent Oxygen
k= 0.008 %/min.
(oxygen utilization rate)
Percent Helium

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